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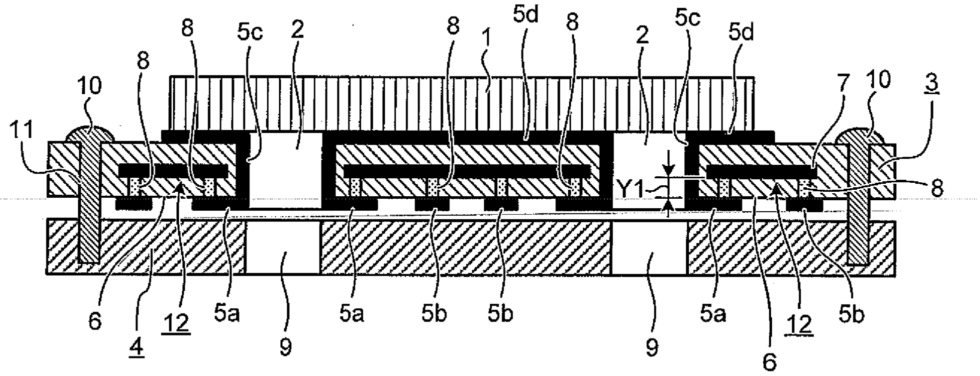
(54) ## WAVEGUIDE CONNECTION STRUCTURE

(57) Provided is a choke structure including: an inside surface conductive pattern 5a formed in the surrounding of a through hole 2 on the surface of a dielectric substrate 3 opposing a waveguide substrate 4; an outside surface conductive pattern 5b formed in the surrounding of the inside surface conductive pattern 5a while being positioned apart therefrom; a conductor opening 6 that is provided between the inside surface conductive pattern 5a and the outside surface conductive pattern 5b and in which a dielectric member is exposed; and an dielectric transmission path 12 short-circuited at end that is formed by an inner layer conductor 7 and a plurality of penetrating conductors 8, the inner layer conductor 7 being provided in a position that is away from the conductor opening 6 by a predetermined distance in the layer-stacking direction of the dielectric substrate 3, and the plurality of penetrating conductors 8 connecting the inner layer conductor 7 to the inside surface conductive pattern 5a and to the outside surface conductive pattern 5b. With the choke structure, it is possible to reduce reflections, passage losses, and leakages of electromagnetic waves, even when a gap occurs between the through hole and the waveguide substrate due to, for example, warpage of the dielectric substrate and the waveguide substrate.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a connection structure of waveguides through which electromagnetic waves are transmitted, the waveguides being provided in a dielectric substrate and in a waveguide substrate that is made of metal or of which one or more surfaces are coated by metal.

BACKGROUND ART

[0002] In a conventional waveguide connection structure, the structure for connecting together a waveguide (i.e., a through hole) through which electromagnetic waves are transmitted and that is provided in an organic dielectric substrate (i.e., a connection member) and another waveguide that is provided in a metal waveguide substrate is configured such that a conductor in the through hole is electrically connected to the metal waveguide substrate so that electric potentials are maintained at the same level, for the purpose of preventing the electromagnetic waves from being reflected, having a passage loss, and leaking at the connection part (see, for example, Patent Document 1).

[0003] Patent Document 1: Japanese Patent Application Laid-open No. 2001-267814 (paragraph [0028] and Fig. 1)

DISCLOSURE OF INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0004] In the conventional waveguide connection structure as described above, there may be a gap between the conductive layer in the through hole and the waveguide substrate due to warpage of the organic dielectric substrate and warpage of the metal waveguide substrate. As a result, a problem arises where the electromagnetic waves are reflected, have a passage loss, or leak, at the connection part.

[0005] In view of the circumstances described above, it is an object of the present invention to obtain a waveguide connection structure with which it is possible to reduce reflections, passage losses, and leakages of the electromagnetic waves, even when there is a gap between the through hole and the waveguide substrate due to, for example, warpage of the dielectric substrate and the waveguide substrate.

MEANS FOR SOLVING PROBLEM

[0006] To achieve the object, a waveguide connection structure according to the present invention includes a dielectric substrate having a through hole of which an inner wall has a conductor provided thereon so that an electromagnetic wave is transmitted through the through hole; and a waveguide substrate that has a waveguide hole and is made of metal or of which a surface is coated by metal, wherein the waveguide connection structure has a choke structure including an inside surface conductive pattern that is formed in a surrounding of the through hole on a surface of the dielectric substrate opposing the waveguide substrate; an outside surface conductive pattern that is formed in a surrounding of the inside surface conductive pattern while being positioned apart from the inside surface conductive pattern; a conductor opening that is provided between the inside surface conductive pattern and the outside surface conductive pattern and in which a dielectric member is exposed; and a dielectric transmission path short-circuited at end that is formed by an inner layer conductor and a plurality of penetrating conductors, the inner layer conductor being provided in a position that is away from the conductor opening by a predetermined distance in a layer-stacking direction of the dielectric substrate, and the plurality of penetrating conductors connecting the inner layer conductor to the inside surface conductive pattern and to the outside surface conductive pattern.

EFFECT OF THE INVENTION

[0007] According to an aspect of the present invention, the dielectric substrate is provided with the choke structure that confines the electromagnetic waves therein. As a result, it is possible to reduce reflections, passage losses, and leakages of the transmitted electromagnetic waves at the waveguide connection part. In addition, because the choke structure is provided in the dielectric substrate that is configured with a material having a higher electric permittivity than that of the air, it is possible to configure the depth of the choke structure so as to be shorter than other choke structure that is formed by, for example, applying a cutting processing to generally-used waveguide substrates. As a result, it is possible to configure a device to which the waveguide connection structure is applied so as to be thin.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is a cross-sectional view of a waveguide connection structure according to a first embodiment of the present invention.

Fig. 2 is a drawing of patterns formed on a surface of a dielectric substrate opposing a waveguide substrate according to the first embodiment of the present invention.

Fig. 3 is a chart of isolation properties between two waveguides that are obtained while a conventional waveguide connection structure is being used.

Fig. 4 is a chart of isolation properties between two waveguides that are obtained according to the first embodiment of the present invention.

Fig. 5 is a cross-sectional view of a waveguide connection structure according to a second embodiment of the present invention.

Fig. 6 is a drawing of patterns formed on the surface of the dielectric substrate opposing the waveguide substrate according to the second embodiment of the present invention.

Fig. 7 is a drawing of patterns formed on an inner layer conductive layer in the dielectric substrate according to the second embodiment of the present invention.

Fig. 8 is a cross-sectional view of a waveguide connection structure according to a third embodiment of the present invention.

Fig. 9 is a drawing of patterns formed on the surface of the dielectric substrate opposing the waveguide substrate according to the third embodiment of the present invention.

Fig. 10 is a drawing of patterns formed on an inner layer conductive layer in the dielectric substrate according to the third embodiment of the present invention.

Fig. 11 is a chart of isolation properties between two waveguides that are obtained while the connection structure according to the third embodiment of the present invention is being used.

Fig. 12 is a cross-sectional view of a waveguide connection structure according to a fourth embodiment of the present invention.

Fig. 13 is a drawing of patterns formed on the surface of the dielectric substrate opposing the waveguide substrate according to the fourth embodiment of the present invention.

Fig. 14 is a drawing of patterns formed on an inner layer conductive layer in the dielectric substrate according to the fourth embodiment of the present invention.

Fig. 15 is a chart of isolation properties between two waveguides that are obtained while the connection structure according to the fourth embodiment of the present invention is being used.

EXPLANATIONS OF LETTERS OR NUMERALS

[0009]

1: High-frequency module
2: Through hole
3: Dielectric substrate
4: Waveguide substrate
5a: Inside surface conductive pattern, Surface conductor
5c: Inner wall conductor
5b: Outside surface conductive pattern
5d: Surface layer ground conductor
6: Conductor opening (opening)
7: Inner layer conductor (Inner layer ground conductor)
8: Penetrating conductor
9: Waveguide hole
10: Screw
11: Through hole
12: dielectric transmission path short-circuited at end
13a: Inside inner layer conductive pattern
13b: Outside inner layer conductive pattern
14: Pattern wiring for signal wirings
15: Penetrating conductor for signal wirings
16: Dielectric layer
17: Dielectric part

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0010] In the following sections, exemplary embodiments of a waveguide connection structure according to the present invention will be described in detail, with reference to the accompanying drawings. The present invention is not limited to these exemplary embodiments.

First Embodiment

[0011] Fig. 1 is a cross-sectional view of a waveguide connection structure according to a first embodiment of the present invention. Fig. 2 is a plan view of patterns formed on a surface of a dielectric substrate 3 opposing a waveguide substrate 4 according to the first embodiment of the present invention. The waveguide connection structure according to the first embodiment is applied to, for example, a millimeter wave radar or a microwave radar such as a Frequency-Modulated Continuous Wave (FM/CW) radar.

[0012] In the multi-layer dielectric substrate 3 on which a high-frequency module 1 including a high-frequency semiconductor is installed, a plurality of through holes 2 that are hollow and rectangular-shaped or cocoon-shaped and that function as waveguides are provided. The waveguide substrate 4 is made of metal or is configured with a resin of which one or more surfaces are coated by metal. In the waveguide substrate 4, a plurality of waveguide holes 9 that are hollow and rectangular-shaped or cocoon-shaped and that function as waveguides are provided. The dielectric substrate 3 and the waveguide substrate 4 are attached together by using screws 10 that are in through holes 11 provided in the dielectric substrate 3, in such a manner that the central axes of the through holes 2 coincide with the central axes of the waveguide holes 9, respectively. In Fig. 1, the gap between the dielectric substrate 3 and the waveguide substrate 4 is exaggerated so that the dielectric substrate 3 and the waveguide substrate 4 seemed to be positioned apart from each other.

[0013] The through holes 2 and the waveguide holes 9 are used for transmitting outgoing electromagnetic wave signals that are output from the high-frequency module 1 to an antenna unit (not shown) or incoming electromagnetic wave signals that are input from the antenna unit to the high-frequency module 1. These outgoing and incoming electromagnetic wave signals are collectively referred to as high-frequency signals.

[0014] An inner wall conductor 5c is provided on an inner circumferential wall of each of the through holes 2 provided in the dielectric substrate 3. Each of the inner wall conductors 5c is connected to a surface layer ground conductor 5d that is provided on the upper surface side of the dielectric substrate 3 and to an inside surface conductive pattern (i.e., a land part) 5a that is formed on the lower surface side (i.e., the side that abuts against the waveguide substrate 4) of the dielectric substrate 3. As shown in Fig. 2, each of the inside surface conductive patterns 5a is formed in a circular shape in the surrounding of the corresponding one of the through holes 2. A ring-shaped conductor opening (hereinafter, the "opening") 6 in which no surface conductor is provided so that the dielectric member is exposed is provided in the surrounding of each of the inside surface conductive patterns 5a. An outside surface conductive pattern 5b is formed in the surrounding of each of the ring-shaped openings 6. In other words, each of the outside surface conductive patterns 5b is formed in the surrounding of the corresponding one of the inside surface conductive patterns 5a, while being positioned apart from the inside surface conductive pattern 5a by a distance that is equal to the width of the corresponding one of the openings 6. In this situation, each of the outside surface conductive patterns 5b is formed so as to have a ring shape and is positioned apart, while the dielectric member is interposed therebetween, from any other outside surface conductive patterns 5b that are formed in the surroundings of the through holes 2 positioned adjacent thereto. As explained here, it is preferable to configure the outside surface conductive patterns 5b that are formed in the surroundings of the ring-shaped openings 6 in such a manner that the outside surface conductive patterns 5b are not connected to one another by conductive patterns, as shown in Fig. 2.

[0015] Each of the inside surface conductive patterns 5a is formed while using the central axis of the corresponding one of the through holes 2 as the center thereof, such that a distance X1 is approximately one fourth (1/4) of a free-space wavelength λ of the high-frequency signal (i.e., the signal wave) transmitted through the through hole 2, where the distance X1 is the distance between a middle point A and an intersection point B, the middle point A being a middle point of a long-side edge (i.e., an E-plane edge) of the through hole 2, and an intersection point B being a point at which a line extended from the middle point A in the direction perpendicular to the long-side edge intersects the edge of the circular-shaped inside surface conductive pattern 5a. The radius R1 of each of the inside surface conductive patterns 5a is equal to the sum of the length X1 (=λ/4) and a length d that is a half of the short side of the through hole 2. In other words, each of the inside surface conductive patterns 5a has the shape of a circle that is centered on the central axis of the through hole 2 and that passes through the point positioned away from the middle point A of the E-plane edge of the through hole 2 by approximately λ/4.

[0016] A plurality of dielectric transmission paths 12, which is short-circuited at end, is provided within the dielectric substrate 3, the dielectric transmission paths 12 short-circuited at end each extending from the corresponding one of the openings 6 in the layer-stacking direction of the dielectric substrate 3 and each having a length of approximately λg/4. In this situation, "λg" denotes an effective wavelength of the high-frequency signal within the dielectric member (i.e., the effective wavelength within the substrate, hereinafter the "in-substrate effective wavelength"). More specifically, an inner layer ground conductor 7 is provided at a position that is away from the surface of the opening 6 by a distance Y1, which is approximately equal to one fourth (1/4) of the in-substrate effective wavelength λg. The inner layer ground conductor 7 is connected to the inside surface conductive patterns 5a and to the outside surface conductive patterns 5b by a plurality of penetrating conductors (ground vias) 8 that each extend in the layer-stacking direction of the substrate. It is desirable to configure each of the intervals between the penetrating conductors 8 so as to be shorter than one fourth (1/4) of the in-substrate effective wavelength λg, and preferably, so as to be equal to or shorter than one eighth (1/8) of the in-substrate effective wavelength λg. As explained here, each of the dielectric transmission paths 12 short-circuited at end is ring shaped in a planar view, is provided so as to extend in the layer-stacking direction of the substrate from the position at which the opening 6 is provided. Each of the dielectric transmission paths 12 short-circuited at end is a region of which the inner circumference and the outer circumference are surrounded by the penetrating conductors 8, whereas the tip end side thereof is enclosed by the inner layer ground conductor 7, while being filled with the dielectric member so that the transmitted electromagnetic waves do not leak therefrom.

[0017] According to the first embodiment, a choke structure is formed by each set made up of the inside surface conductive pattern 5a, the outside surface conductive pattern 5b, the opening 6, and the dielectric transmission path 12 short-circuited at end.

[0018] When a choke structure as described above is adopted, a short circuit is achieved by the inner layer conductor 7 with the arrangements in which the distance Y1 is configured so as to be approximately equal to λg/4, whereas the distance X1 is configured so as to be approximately equal to λ/4. As a result, the edge (e.g., the point B) of the inside surface conductive pattern 5a is equivalent as being open for the transmitted electromagnetic waves. Further, the long-side edges (i.e., the E-plane) of the through hole 2 that are positioned away from this edge by the distance approximately equal to λ/4 is equivalent as being short-circuited. With this arrangement, it is possible to inhibit the signals from leaking at the connection parts between the through holes 2 provided in the dielectric substrate 3 and the waveguide holes 9 provided in the waveguide substrate 4. Consequently, it is possible to inhibit the signals from leaking into adjacent waveguide connection structure parts and to enhance the isolation properties. Furthermore, even if some signals have leaked, because each of the outside surface conductive patterns 5b is formed independently such that the patterns are separated from one another corresponding to the different waveguide connection structures, it is possible to cut off the transmission of the leaked signals in a parallel plate mode and to further enhance the level of isolation.

[0019] The dielectric member included in the dielectric substrate 3 has a relative permittivity that is larger than 1, so that the effective wavelength of the electromagnetic waves within the dielectric member is shorter than that in the air. Thus, it is possible to configure the depth of the choke structure so as to be shorter than that of other choke structures in general that are formed by, for example, a cutting process and are filled with air. For example, one fourth (1/4) of the free-space wavelength (in the air) of the signal electromagnetic waves at 76 gigahertz (GHz) to 77 gigahertz used in an FM/CW radar installed in an automobile is approximately 0.98 millimeters. Thus, in the case where a choke structure is formed by a cutting process, the depth of the choke structure is approximately 0.98 millimeters. In contrast, because the relative permittivity of a generally-used glass epoxy substrate is approximately 4, one fourth (1/4) of the in-substrate effective wavelength λg is approximately 0.49 millimeters.

[0020] For example, in the case where a glass epoxy substrate having a thickness of 1.0 millimeter is adopted as the dielectric substrate 3, if a choke structure was formed by performing a cutting processing and further providing a conductor therein by performing a plate processing or the like, the thickness of the substrate in a cut part would be approximately 0.02 millimeters, and it would be extremely difficult to achieve such choke structure. In contrast, by configuring the choke structure with the patterns on the substrate such that the inside thereof is filled with the resin as described in the first embodiment, it is possible to configure the depth so as to be approximately 0.49 millimeters and achieve the desired choke structure easily. Further, even in a case where the thickness of the substrate is large enough to form a choke structure by performing a cutting processing, it is possible to keep the volume of the choke structure occupying the inside of the substrate small according to the first embodiment. Thus, by using the configuration according to the first embodiment, it is possible to configure the entirety of the device so as to be thin and compact.

[0021] Fig. 3 is a chart of a result of a simulation indicating isolation properties between two waveguide connection structures positioned adjacent to each other, when adopting a conventional waveguide connection structure having no choke structure. Fig. 4 is a chart of a result of a simulation indicating isolation properties between two waveguide connection structures positioned adjacent to each other, when adopting the choke structure according to the first embodiment. In the example of the conventional waveguide connection structure of which the isolation properties are shown in Fig. 3, the entirety of the surface of the dielectric substrate 3 opposing the waveguide substrate 4 is covered with a conductor. The dimension of each of the through holes 2 is configured to be 2.50 millimeters by 0.96 millimeters so as to conform to the high-frequency module 1, whereas the dimension of each of the waveguide holes 9 is configured to be 2.54 millimeters by 1.27 millimeters. The thickness of the dielectric substrate 3 is 1.6 millimeters, whereas the dielectric member is made of a glass epoxy material, and the relative permittivity thereof is 4.0. The pitch between the two waveguide holes 9, 9 is 3.5 millimeters, whereas the gap between the dielectric substrate 3 and the waveguide substrate 4 is 0.2 millimeters. In contrast, in the example of the waveguide connection structure according to the first embodiment of which the isolation properties are shown in Fig. 4, the choke structure described above is provided in the conventional waveguide connection structure having the dimensions described above. The radius R1 of each of the inside surface conductive patterns 5a connected to the corresponding one of the through holes 2 is 1.6 millimeters, whereas the outer radius R2 of each of the openings 6 in which the dielectric member is exposed is 2.6 millimeters. The distance Y1 between the surface of the substrate and the inner layer conductor 7 is approximately 0.5 millimeters, whereas the width of each of the outside surface conductive patterns 5b is 0.6 millimeters. As apparent from a comparison between Fig. 3 and Fig. 4, the waveguide connection structure according to the first embodiment exhibits isolation properties that are improved by 65 decibel (dB) or more, at 76 gigahertz to 77 gigahertz, which is a band used by FM/CW radars installed in automobiles. Thus, it has been confirmed that it is possible to achieve a very advantageous effect.

[0022] In Figs. 1 and 2, each of the inside surface conductive patterns 5a is circular shaped, whereas each of the openings 6 and each of the outside surface conductive patterns 5b is circular ring (annular) shaped. However, another arrangement is acceptable in which each of the inside surface conductive patterns 5a is polygonal shaped or the like, whereas each of the openings 6 and each of the outside surface conductive patterns 5b is polygonal ring (annular) shaped.

Second Embodiment

[0023] Next, a second embodiment of the present invention will be explained, with reference to Figs. 5 to 7. Fig. 5 is a cross-sectional view of a waveguide connection structure according to the second embodiment. Fig. 6 is a plan view of patterns formed on the surface of the dielectric substrate 3 opposing the waveguide substrate 4 according to the second embodiment. Fig. 7 is a drawing (i.e., a cross-sectional view at the line C-C in Fig. 5) of patterns of the conductor formed within the dielectric substrate 3 on such a layer that is positioned more inward, by one layer, than the lower surface layer of the dielectric substrate 3, according to the second embodiment. According to the second embodiment, a dielectric layer 16 that is formed by using a build-up method or the like is provided on the surface of the dielectric substrate 3 opposing the waveguide substrate 4. In the following sections, only the configurations that are different from those of the first embodiment will be explained. Explanation of the duplicate configurations will be omitted.

[0024] As shown in Figs. 5 and 6, surface conductors 5a are provided on the surface of the dielectric substrate 3 opposing the waveguide substrate 4, the surface conductors 5a each having a required minimum dimension to provide the inner wall of the corresponding one of the through holes 2 with the conductor. There is no other surface conductor, and the dielectric layer 16 is thus exposed.

[0025] As shown in Figs. 5 and 7, a choke structure that is the same as the one explained in the first embodiment is formed so as to extend from such an inner layer of the dielectric substrate 3 that is positioned more inward, by one layer, than the surface conductor 5a, toward the further inner layers. More specifically, an inside inner layer conductive pattern 13a, which is circular shaped, is formed in the surrounding of each of the through holes 2 on such an inner layer of the dielectric substrate 3 that is positioned more inward, by one layer, than the surface conductor 5a, while being connected to the inner wall conductor 5c. A dielectric part 17 that is ring shaped and is made of a dielectric member without any conductor is provided in the surrounding of each of the inside inner layer conductive patterns 13a. An outside inner layer conductive pattern 13b, which is ring shaped, is formed in the surrounding of each of the dielectric parts 17. The outside inner layer conductive patterns 13b that are formed in the surroundings of the through holes 2, which are positioned adjacent to one another, are positioned apart from one another, while the dielectric member is interposed therebetween.

[0026] Like in the first embodiment, each of the inside inner layer conductive patterns 13a is formed while using the central axis of the corresponding one of the through holes 2 as the center thereof, such that the distance X1 is approximately one fourth (1/4) of the free-space wavelength λ of the signal wave transmitted through the through hole 2, where the distance X1 is the distance between a middle point A' and an intersection point B'. The middle point A' is a middle point of a long-side edge (i.e., an E-plane edge) of the through hole 2, and the intersection point B' is a point at which a line extending from the middle point A' in the direction perpendicular to the long-side edge intersects the edge of the circular-shaped inside inner layer conductive pattern 13a. The radius R1 of each of the inside inner layer conductive patterns 13a is equal to the sum of the length X1 (=λ/4) and the length d that is a half of the short side of the through hole 2.

[0027] Each of the dielectric transmission paths 12 short-circuited at end is provided within the dielectric substrate 3, so as to extend from the dielectric part 17 in the layer-stacking direction of the dielectric substrate 3. More specifically, the inner layer ground conductor 7 is provided at a position that is away from the surface of the dielectric substrate 3 opposing the waveguide substrate 4 by the distance Y1 (=λg/4). The inner layer ground conductor 7 is connected to the inside inner layer conductive patterns 13a and to the outside inner layer conductive patterns 13b by the plurality of penetrating conductors 8 that each extend in the layer-stacking direction of the substrate. It is desirable to configure a thickness Y2 of the dielectric layer 16 that is formed by using a build-up method or the like on the surface of the dielectric substrate 3 opposing the waveguide substrate 4 so as to be very small, and preferably, so much smaller than the distance Y1 that the thickness Y2 is negligible. As explained here, each of the dielectric transmission paths 12 short-circuited at end having a ring shape in a planar view is provided within the dielectric substrate 3, the dielectric transmission paths 12 short-circuited at end each being a region of which the inner circumference and the outer circumference are surrounded by the penetrating conductors 8, whereas the tip end side thereof is enclosed by the inner layer ground conductor 7, while being filled with the dielectric member so that the transmitted electromagnetic waves do not leak therefrom.

[0028] According to the second embodiment, because the dielectric transmission paths 12 short-circuited at end and the inside inner layer conductive patterns 13a are provided, short circuits are equivalently achieved in connection parts between the inside inner layer conductive patterns 13a and the inner wall conductors 5c provided on the inner walls of the through holes 2. In addition, in the case where the width of each of the surface conductors 5a is configured so as to be small, and further, the thickness Y2 of the dielectric layer 16 is configured so as to be very small by using a build-up method or the like as explained above, for example, comparing with the distance Y1 that the thickness Y2 is negligible, short circuits are equivalently achieved also in the connection parts between the through holes 2 and the waveguide holes 9. With these arrangements, it is possible to inhibit the signals from leaking at the connection parts between the through holes 2 provided in the dielectric substrate 3 and the waveguide holes 9 provided in the waveguide substrate 4. As a result, it is possible to inhibit the signals from leaking into adjacent waveguide connection structure parts and to enhance the isolation properties.

[0029] Furthermore, the surface conductors 5b, which are provided according to the first embodiment, are not provided according to the second embodiment. Thus, when the dielectric substrate 3 and the waveguide substrate 4 are joined together, an advantageous effect is achieved where it becomes easier for the surface conductor 5a to come in contact, thus it is less likely that the through holes 2 and the waveguide holes 9 have gaps therebetween.

[0030] Choke structures that has an advantageous effect of confining electromagnetic waves therein like the dielectric transmission paths 12 short-circuited at end are originally designed so as to function when a gap has occurred in the connection parts. Thus, by providing the dielectric layer 16 like in the second embodiment, it is possible to allow the choke structure provided in the dielectric substrate 3 and the waveguide substrate 4 to have a certain gap therebetween. Thus, another advantageous effect is achieved where it is easier to achieve the electromagnetic wave confining effect of the dielectric transmission paths 12 short-circuited at end, stably.

[0031] In addition, according to the second embodiment, because the dielectric layer 16 is provided, a pattern wiring for signal wirings 14 and a penetrating conductor for signal wirings 15 that are provided within the dielectric substrate 3 are not connected up to the surface of the dielectric substrate 3 that is in contact with the waveguide substrate 4. As a result, yet another advantageous effect is achieved where it is not necessary to provide the surface of the dielectric substrate 3 that is in contact with the waveguide substrate 4 with any special electrically-insulating structure.

[0032] It is desirable if each of the surface conductors 5a according to the second embodiment is configured so as to have a required minimum width to provide the inner wall of the through hole with the inner wall conductor 5c; however, even if each of the surface conductors 5a is configured so as to extend from the inner wall conductor 5c to a position that is more inward than the end edge of the inside inner layer conductive pattern 13a, it is possible to make the isolation properties better than in the conventional example.

Third Embodiment

[0033] Next, a third embodiment of the present invention will be explained with reference to Figs. 8 to 11. Fig. 8 is a cross-sectional view of a waveguide connection structure according to the third embodiment. Fig. 9 is a plan view of patterns formed on the surface of the dielectric substrate 3 opposing the waveguide substrate 4 according to the third embodiment. Fig. 10 is a drawing (i.e., a cross-sectional view at the line C-C in Fig. 8) of patterns of the conductor formed within the dielectric substrate 3 on such a layer that is positioned more inward, by one layer, than the lower surface layer of the dielectric substrate 3, according to the third embodiment.

[0034] According to the third embodiment, like in the second embodiment, the dielectric layer 16 that is formed by using a build-up method or the like is provided on the surface of the dielectric substrate 3 opposing the waveguide substrate 4. In addition, the inside surface conductive patterns 5a and the outside surface conductive patterns 5b, which are the same as those in the first embodiment, are further formed on the surface of the dielectric layer 16. It should be noted, however, that the inside surface conductive patterns 5a are not connected to the inside inner layer conductive patterns 13a by the penetrating conductors 8 and that the outside surface conductive patterns 5b are not connected to the outside inner layer conductive patterns 13b by the penetrating conductors 8, either.

[0035] As shown in Figs. 8 and 9, each of the inside surface conductive patterns 5a, which is circular shaped, is formed in the surrounding of the corresponding one of the through holes 2 on the surface of the dielectric layer 16, while being connected to the inner wall conductor 5c. Each of the ring-shaped conductor openings 6, in which no conductor is provided so that the dielectric member is exposed, is provided in the surrounding of the corresponding one of the inside surface conductive patterns 5a. Further, each of the ring-shaped outside surface conductive patterns 5b is formed in the surrounding of the corresponding one of the conductor openings 6. The outside surface conductive patterns 5b that are formed in the surroundings of the through holes 2, which are positioned adjacent to one another, are positioned apart from one another, while the dielectric member is interposed therebetween. Like in the first embodiment, each of the inside surface conductive patterns 5a is formed while using the central axis of the corresponding one of the through holes 2 as the center thereof, such that the distance X1 is approximately equal to $\lambda/4$, where the distance X1 is the distance between the middle point A and the intersection point B. The middle point A is a middle point of the long-side edge (i.e., the E-plane edge) of the through hole 2, and the intersection point B is a point at which a line extending from the middle point A in the direction perpendicular to the long-side edge intersects the edge of the circular-shaped inside surface conductive pattern 5a. The radius R1 of each of the inside surface conductive patterns 5a is equal to the sum of the length X1 ($=\lambda/4$) and the length d that is a half of the short side of the through hole 2.

[0036] As shown in Figs. 8 and 10, a choke structure that is the same as the one explained in the second embodiment is formed on an inner layer of the dielectric substrate 3. More specifically, on such an inner layer of the dielectric substrate 3 that is positioned more inward, by one layer, than the inside surface conductive pattern 5a, each of the circular-shaped inside inner layer conductive patterns 13a is formed in the surrounding of the corresponding one of the through holes 2, while being connected to the inner wall conductor 5c. Each of the ring-shaped dielectric parts 17 that is made of the dielectric member with no conductor, is provided in the surrounding of the corresponding one of the inside inner layer conductive patterns 13a. Each of the ring-shaped outside inner layer conductive patterns 13b is formed in the surrounding of the corresponding one of the dielectric parts 17. The outside inner layer conductive patterns 13b that are formed in the surroundings of the through holes 2, which are positioned adjacent to one another, are positioned apart from one another, while the dielectric member is interposed therebetween. Like in the second embodiment, each of the inside inner layer conductive patterns 13a is formed while using the central axis of the corresponding one of the through holes 2 as the center thereof, such that the distance X1 is approximately equal to λ/4, where the distance X1 is the distance between the middle point A' and the intersection point B'. The middle point A' is a middle point of the long-side edge (i.e., the E-plane edge) of the through hole 2, and the intersection point B' is a point at which a line extended from the middle point A' in the direction perpendicular to the long-side edge intersects the edge of the circular-shaped inside inner layer conductive pattern 13a. The radius R1 of each of the inside inner layer conductive patterns 13a is equal to the sum of the length X1 (=λ/4) and the length d that is a half of the short side of the through hole 2.

[0037] Each of the dielectric transmission paths 12 short-circuited at end is provided within the dielectric substrate 3, so as to extend from the dielectric part 17 in the layer-stacking direction of the dielectric substrate 3. More specifically, the inner layer ground conductor 7 is provided at the position that is away from the surface of the dielectric substrate 3 opposing the waveguide substrate 4 by the distance Y1 (=λg/4). The inner layer ground conductor 7 is connected to the inside inner layer conductive patterns 13a and to the outside inner layer conductive patterns 13b by the plurality of penetrating conductors 8 that each extend in the layer-stacking direction of the substrate. It is desirable to configure the thickness Y2 of the dielectric layer 16 that is formed by using a build-up method or the like on the surface of the dielectric substrate 3 opposing the waveguide substrate 4 so as to be very small, and preferably, so much smaller than the distance Y1 that the thickness Y2 is negligible. As explained here, each of the dielectric transmission paths 12 short-circuited at end is ring shaped in a planar view and is provided within the dielectric substrate 3. Each of the dielectric transmission paths 12 short-circuited at end is a region of which the inner circumference and the outer circumference are surrounded by the penetrating conductors 8, whereas the tip end side thereof is enclosed by the inner layer ground conductor 7, while being filled with the dielectric member so that the transmitted electromagnetic waves do not leak therefrom.

[0038] Fig. 11 is a chart of a result of a simulation indicating isolation properties between two waveguide connection structures that are positioned adjacent to each other, when adopting the choke structure according to the third embodiment. In this situation, the thickness Y2 of the dielectric layer 16 is configured to be 0.070 millimeters. The other dimensions are the same as those in the first embodiment as shown in Fig. 4. As understood from Figs. 4 and 11, isolations properties that are substantially the same as those according to the first embodiment are achieved in the third embodiment as well. Thus, by forming the dielectric layer 16 on the surface of the dielectric substrate 3 opposing the waveguide substrate 4 by using a build-up method or the like, it is possible to achieve the isolation properties that are substantially the same as those in the first embodiment, even in the case where the penetrating conductive patterns 8 are not connecting the inside surface conductive patterns 5a to the inside inner layer conductive patterns 13a and where the penetrating conductors 8, are not connecting the outside surface conductive patterns 5b to the outside inner layer conductive patterns 13b. By using a structure like this, it is not necessary to provide the penetrating conductors 8, which are formed by applying a laser processing or a plate processing to the dielectric substrate 3, so as to connect the inside surface conductive patterns 5a to the inside inner layer conductive patterns 13a and to further connect the outside surface conductive patterns 5b to the outside inner layer conductive pattern 13b. Thus, another advantageous effect is achieved where it is possible to easily structure the dielectric substrate 3 at a lower cost.

Fourth Embodiment

[0039] Next, a fourth embodiment of the present invention will be explained with reference to Figs. 12 to 15. Fig. 12 is a cross-sectional view of a waveguide connection structure according to the fourth embodiment. Fig. 13 is a plan view of patterns formed on the surface of the dielectric substrate 3 opposing the waveguide substrate 4 according to the fourth embodiment. Fig. 14 is a drawing (i.e., a cross-sectional view at the line C-C in Fig. 12) of patterns of the conductor formed within the dielectric substrate 3 on such a layer that is positioned more inward, by one layer, than the lower surface layer of the dielectric substrate 3, according to the fourth embodiment.

[0040] According to the third embodiment, the outside surface conductive patterns 5b, each of which is formed in the surrounding of the corresponding one of the inside surface conductive patterns 5a while the conductor opening 6 in which the dielectric member is exposed is interposed therebetween, are separated from one another in correspondence with each of the waveguide connection structures. Also, the outside inner layer conductive patterns 13b, each of which is formed in the surrounding of the corresponding one of the inside inner layer conductive patterns 13a while the dielectric part 17 that is made of the dielectric member without having any conductor is interposed therebetween, are separated from one another in correspondence with each of the waveguide connection structures. In contrast, according to the fourth embodiment, as shown in Figs. 13 and 14, the outside surface conductive pattern 5b is formed as being joined together for all the waveguide connection structures, and also, the outside inner layer conductive pattern 13b is formed as being joined together for all the waveguide connection structures. In the example shown in Figs. 13

and 14, the outside surface conductive pattern 5b and the outside inner layer conductive pattern 13b are each indicated as a ground pattern that spreads as a solid pattern. The other configurations are the same as those in the third embodiment. The duplicate explanation will be omitted.

[0041] Fig. 15 is a chart of a result of a simulation indicating isolation properties between two waveguide connection structures that are positioned adjacent to each other, when adopting the choke structure according to the fourth embodiment. In this situation, the thickness Y2 of the dielectric layer 16 is configured to be 0.070 millimeters. The other dimensions are the same as those in the first embodiment shown in Fig. 4. As shown in Fig. 13, the surface of the dielectric substrate 3 in the surroundings of the inside surface conductive patterns 5a is covered by the outside surface conductive pattern 5b, which spreads as the solid pattern. Also, as shown in Fig. 14, the circumferences of the inside inner layer conductive patterns 13a are surrounded by the outside inner layer conductive pattern 13b, which spreads as the solid pattern. As understood from a comparison of Figs. 4, 11, and 15, the isolation properties according to the fourth embodiment are slightly worse than those in the examples in the first and the third embodiments; however, the isolation properties are better than those according to the conventional technique shown in Fig. 3.

[0042] As described above, according to the second, the third, and the fourth embodiments, the dielectric layer 16 is provided on the surface of the dielectric substrate 3 opposing the waveguide substrate 4, and the surface conductor having the various types of patterns is provided on the surface side of the dielectric layer 16. As shown in Fig. 13, by configuring the surface conductor so as to spread outward from the inner wall conductors 5c on the surface of the dielectric layer 16, in such a manner that the surface conductor does not cover the dielectric parts 17 (see Figs. 7 and 10) provided between the inside inner layer conductive patterns 13a and the outside inner layer conductive patterns 13b, it is possible to make the isolation properties better than those according to the conventional technique.

[0043] In the third and the fourth embodiments described above, the surface conductors 5a and 5b as well as the inner layer conductors 13a and 13b are not connected to one another by the penetrating conductors 8; however, another arrangement is acceptable in which they are connected to one another by the penetrating conductors 8. Further, when a third inner layer conductor is provided between the inner layer conductors 13a and 13b and the inner layer conductor 7, and when the distance between the inner layer conductor 7 and the third inner layer conductor or the distance between the inner layer conductors 13a and 13b and the third inner layer conductor is configured to be shorter than λg/4, and preferably, to be equal to or shorter than λg/8, the effect of shielding the transmitted electromagnetic waves will be large enough. Thus, yet another arrangement is acceptable in which the penetrating conductors 8 that connect the inner layer conductors 13a and 13b to the inner layer conductor 7 are omitted.

[0044] In the first through the fourth embodiments described above, the choke structure is applied to both of the two waveguide connection structures. However, there is no restriction as to how many choke structures should be provided. Thus, as long as the isolation properties are at a satisfying level, it is acceptable to apply the choke structure according to any of the first through the fourth embodiments to only a part of the waveguide connection structures, instead of applying the choke structure to all the waveguide connection structures.

INDUSTRIAL APPLICABILITY

[0045] As explained above, the waveguide connection structure according to an aspect of the present invention is useful as a connection structure between a dielectric substrate and a waveguide substrate, the dielectric substrate having through holes of which the inner walls have conductors provided thereon so that electromagnetic waves can be transmitted through the through holes, and the waveguide substrate having waveguide holes and being made of metal or having one or more surfaces thereof coated by metal.

Claims

1. A waveguide connection structure that includes a dielectric substrate (3) having a through hole (2) of which an inner wall has a conductor provided thereon so that an electromagnetic wave is transmitted through the through hole (2); and a waveguide substrate (4) that has a waveguide hole (9) and is made of metal or of which a surface is coated by metal, wherein the waveguide connection structure has a choke structure including an inside surface conductive pattern (5a) that is formed in a surrounding of the through hole (2) on a surface of the dielectric substrate (3) opposing the waveguide substrate (4); an outside surface conductive pattern (5b) that is formed in a surrounding of the inside surface conductive pattern (5a) while being positioned apart from the inside surface conductive pattern (5a);
a conductor opening (6) that is provided between the inside surface conductive pattern (5a) and the outside surface conductive pattern (5b) and in which a dielectric member is exposed; and a dielectric transmission path (12) short-circuited at end that is formed by an inner layer conductor (7) and a plurality of penetrating conductors (8), the inner layer conductor (7) being provided in a position that is away from the conductor opening (6) by a predetermined distance in a layer-stacking direction of the dielectric substrate (3), and the plurality of penetrating conductors (8) connecting the inner layer conductor to the inside

surface conductive pattern (5a) and to the outside surface conductive pattern (5b).

2. The waveguide connection structure according to claim 1, wherein
the through hole (2) and the waveguide hole (9) are both rectangular-shaped or cocoon-shaped, the inside surface conductive pattern (5a) is circular shaped that is centered on a central axis of the through hole (2) and that passes through a point positioned away from a middle point of an E-plane edge of the through hole (2) by approximately λ/4 (where λ denotes a free-space wavelength of a signal wave), and the conductor opening (6) is ring shaped that is formed in a surrounding of the inside surface conductive pattern (5a) which is circular shaped.

3. The waveguide connection structure according to claim 1 or 2, wherein a distance from the surface of the dielectric substrate (3) opposing the waveguide substrate (4) to the inner layer conductor (7) is approximately equal to one fourth of an in-substrate effective wavelength of the signal wave.

4. A waveguide connection structure that includes a dielectric substrate (3) having a through hole (2) of which an inner wall has a conductor provided thereon so that an electromagnetic wave is transmitted through the through hole (2); and a waveguide substrate (4) that has a waveguide hole (9) and is made of metal or of which a surface is coated by metal, wherein the waveguide connection structure has a choke structure including an inside inner layer conductive pattern (13a) that is formed in a surrounding of the through hole (2) on an inner layer of the dielectric substrate (3); an outside inner layer conductive pattern (13b) that is formed in a surrounding of the inside inner layer conductive pattern (13a) on the inner layer of the dielectric substrate (3) while being positioned apart from the inside inner layer conductive pattern (13a); a dielectric part (17) that is positioned between the inside inner layer conductive pattern (13a) and the outside inner layer conductive pattern (13b); a dielectric transmission path (12) short-circuited at end that is formed by an inner layer conductor (7) and a plurality of penetrating conductors (8), the inner layer conductor (7) being provided in a position that is apart from the dielectric part (17) by a predetermined distance in a layer-stacking direction of the dielectric substrate (3), and the plurality of penetrating conductors (8) connecting the inner layer conductor (7) to the inside inner layer conductive pattern (13a) and to the outside inner layer conductive pattern (13b); a surface dielectric layer (16) that is provided on the inside inner layer conductive pattern (13a) and the outside inner layer conductive pattern (13b) so as to oppose the waveguide substrate (4); and a surface conductor (5a; 5a, 5b, 6) that is provided in a surrounding of the through hole (2) on the surface dielectric layer (16), which is a surface of the dielectric substrate (3) opposing the waveguide substrate (4), while extending outward from the conductor provided on the inner wall of the through hole (2) such that the dielectric part (17) is not covered thereby.

5. The waveguide connection structure according to claim 4, wherein the surface conductor (5a) extends from the conductor provided on the inner wall of the through hole (2) up to a position that is more inward than an edge position of the inside inner layer conductive pattern (13a), and the surface conductor (5a) has a required minimum width to provide the inner wall of the through hole (2) with the conductor.

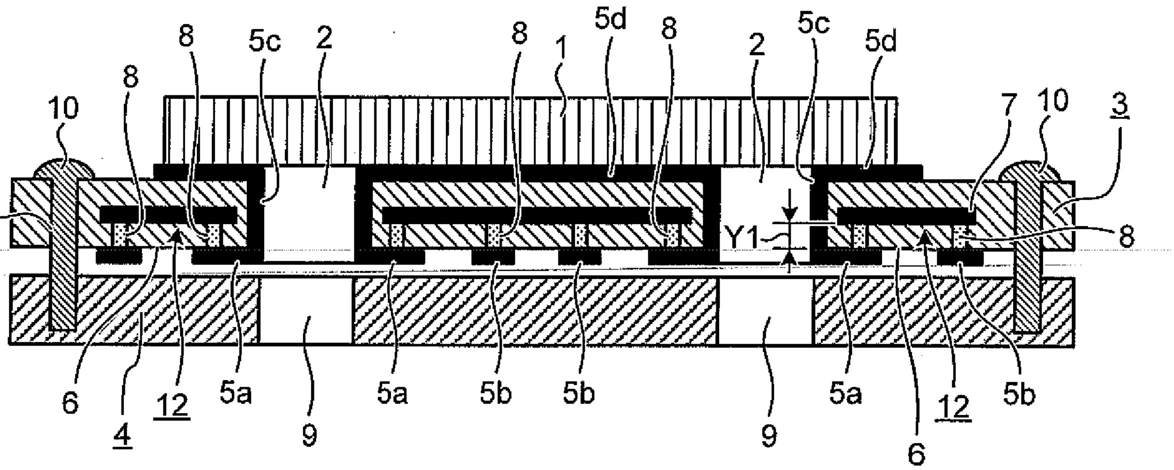
6. The waveguide connection structure according to claim 5, wherein the through hole (2) and the waveguide hole (9) are both rectangular-shaped or cocoon-shaped, the inside inner layer conductive pattern (13a) is circular shaped that is centered on a central axis of the through hole (2) and that passes through a point positioned away from a middle point of an E-plane edge of the through hole by approximately λ/4 (where λ denotes a free-space wavelength of a signal wave), and the dielectric part (17) is ring shaped that is formed in a surrounding of the inside inner layer conductive pattern (13a) which is circular shaped.

7. The waveguide connection structure according to claim 4, wherein the surface conductor (5a, 5b, 6) includes: an inside surface conductive pattern (5a) that is formed in the surrounding of the through hole (2) on the surface dielectric layer (16), which is the surface of the dielectric substrate (3) opposing the waveguide substrate (4);
an outside surface conductive pattern (5b) that is formed in a surrounding of the inside surface conductive pattern (5b) while being positioned apart from the inside surface conductive pattern (5a); and a conductor opening (6) that is provided between the inside surface conductive pattern (5a) and the outside surface conductive pattern (5b) and in which the dielectric member is exposed.

8. The waveguide connection structure according to claim 7, wherein the through hole (2) and the waveguide hole (9) are both rectangular-shaped or cocoon-shaped, the inside inner layer conductive pattern (13a) is circular shaped that is centered on a central axis of the through hole (2) and that passes through a point positioned away from a middle point of an E-plane edge of the through hole (2) by approximately λ/4 (where λ denotes a free-space wavelength of a signal wave), the dielectric part (17) is ring shaped that is formed in a surrounding of the inside inner layer conductive pattern (13a) which is circular shaped, the inside surface conductive pattern (5a) is circular shaped that is centered on the central axis of the through hole (2) and that passes through a point positioned away from the middle point of the E-plane edge of the through hole (2) by approximately λ/4 (where λ denotes the free-space wavelength of the signal wave), and the conductor opening (6) is ring shaped that is formed in a surrounding of the inside surface conductive pattern (5a) which is circular shaped.

9. The waveguide connection structure according to any one of claims 4 to 8, wherein a distance from the surface of the dielectric substrate (3) opposing the waveguide substrate (4) to the inner layer conductor (7) is approximately equal to one fourth of an in-substrate effective wavelength of the signal wave.

FIG.1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12
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9
5a
5b
5b
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5a
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12
5b

FIG.2

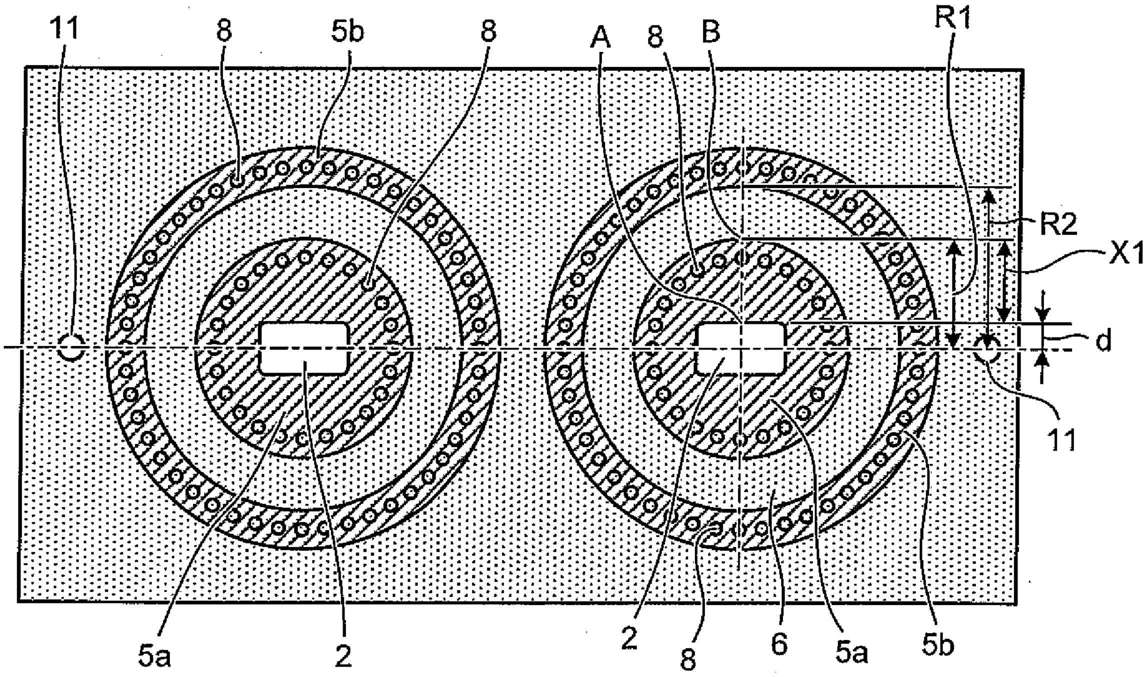
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FIG.3

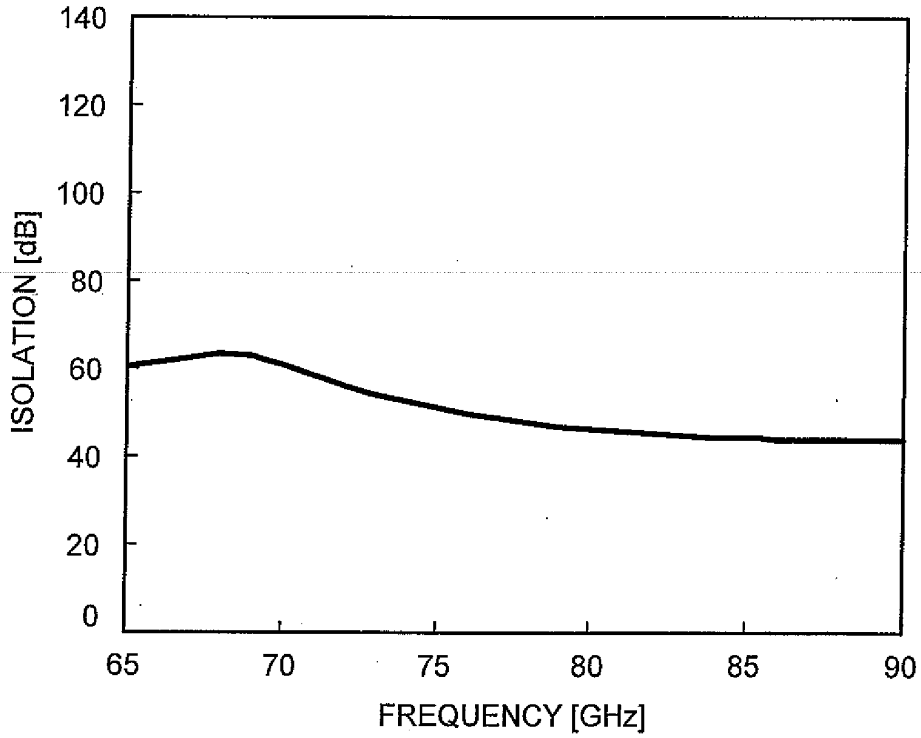
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FIG.4

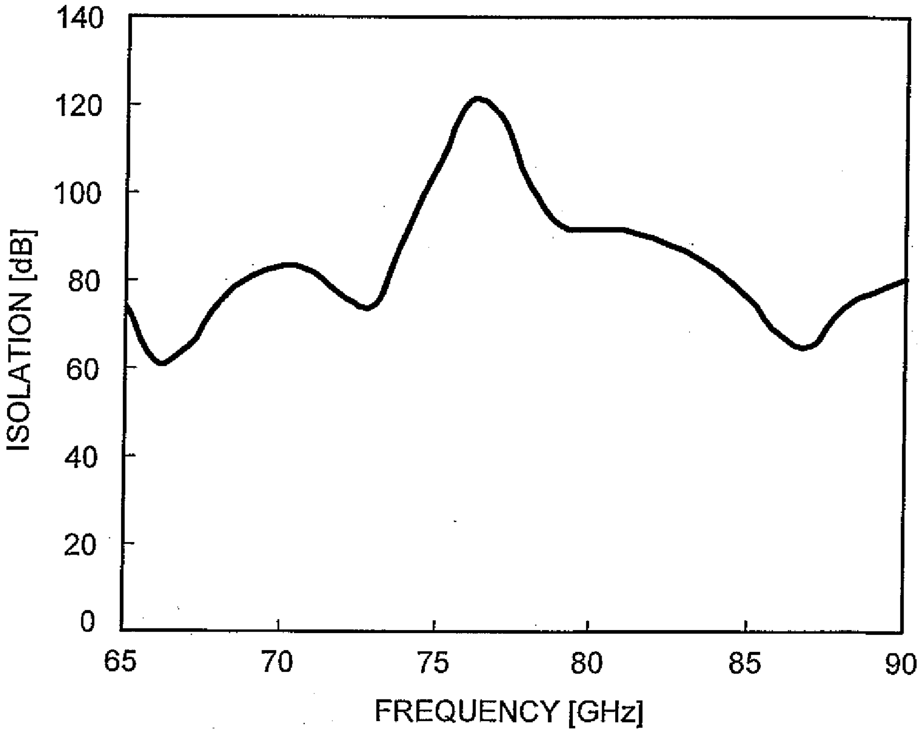
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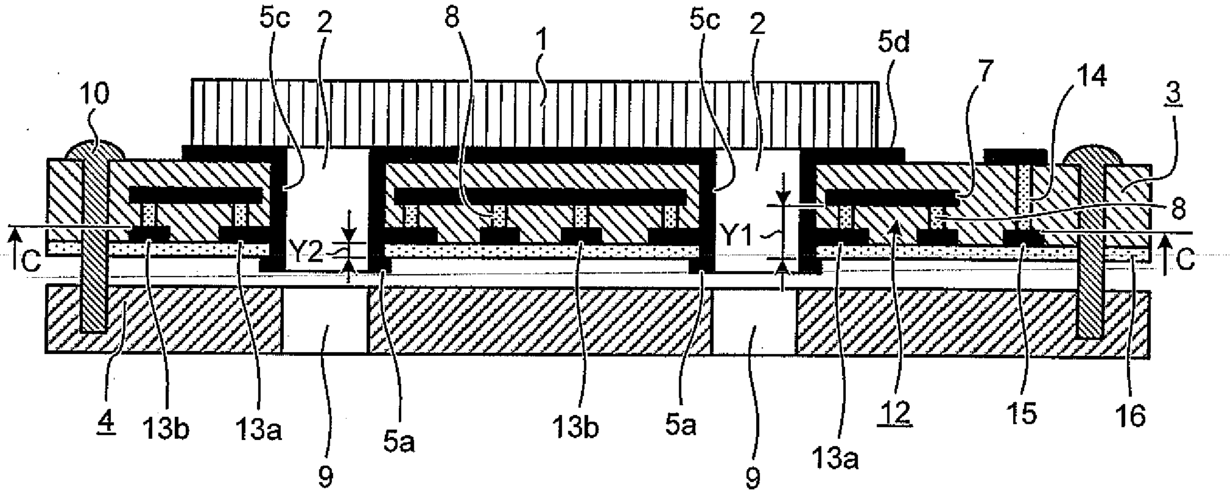
FIG.5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14
3
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5a
9
13b
5a
9
13a
12
15
16

FIG.6

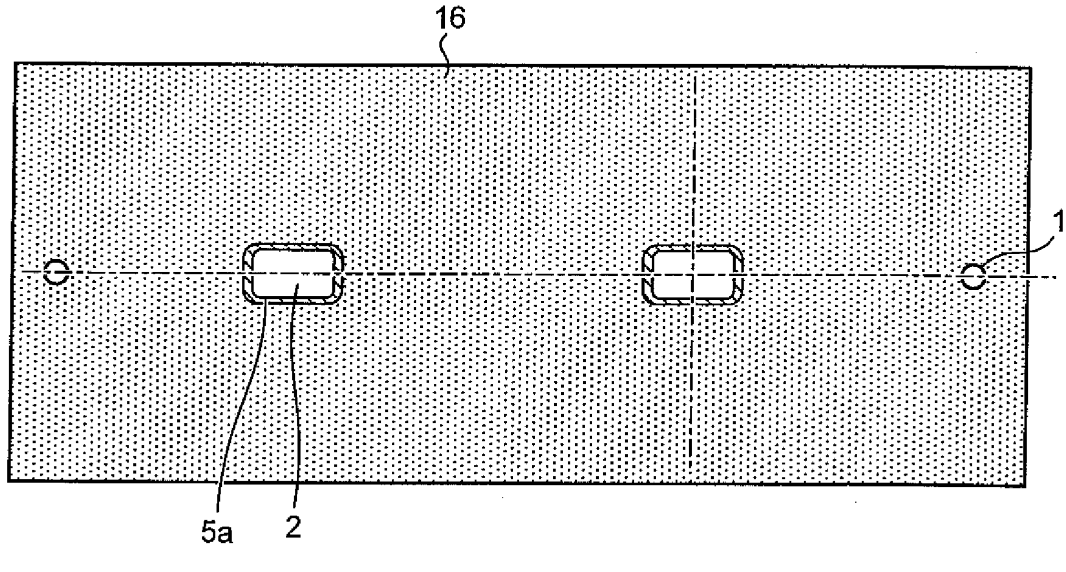
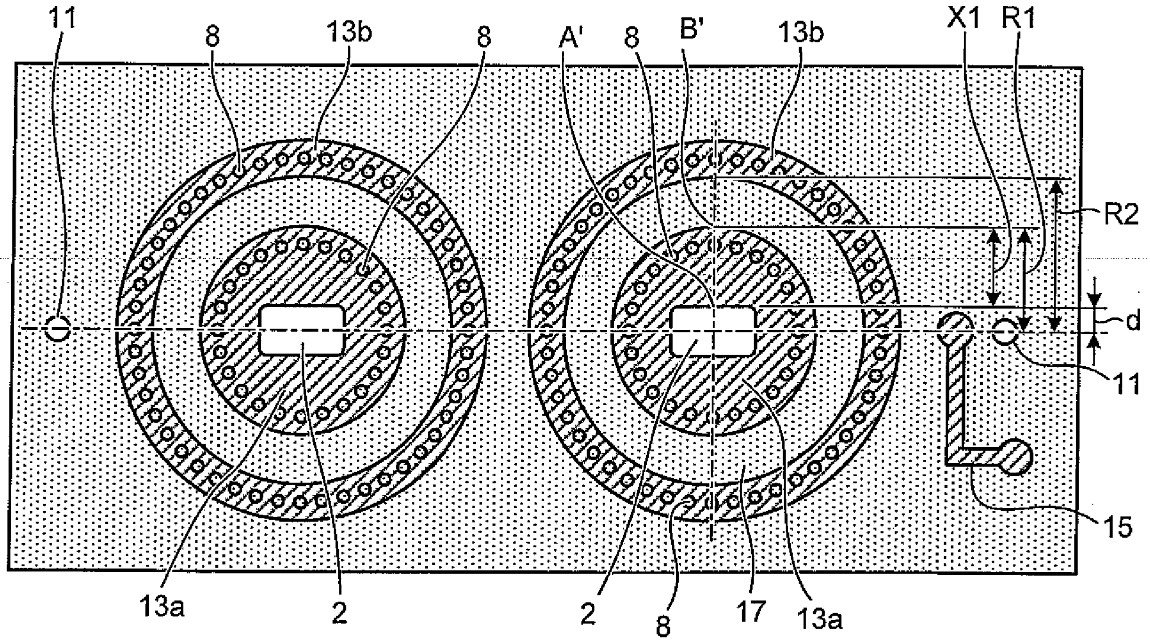

16
11
5a
2

FIG.7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13b
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A'
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13a
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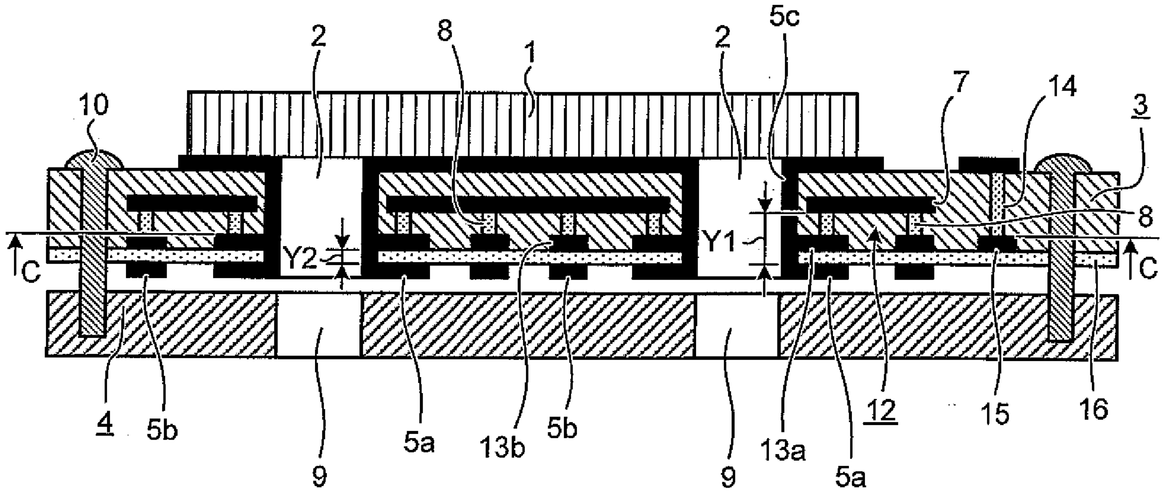
8
17
13a

FIG.8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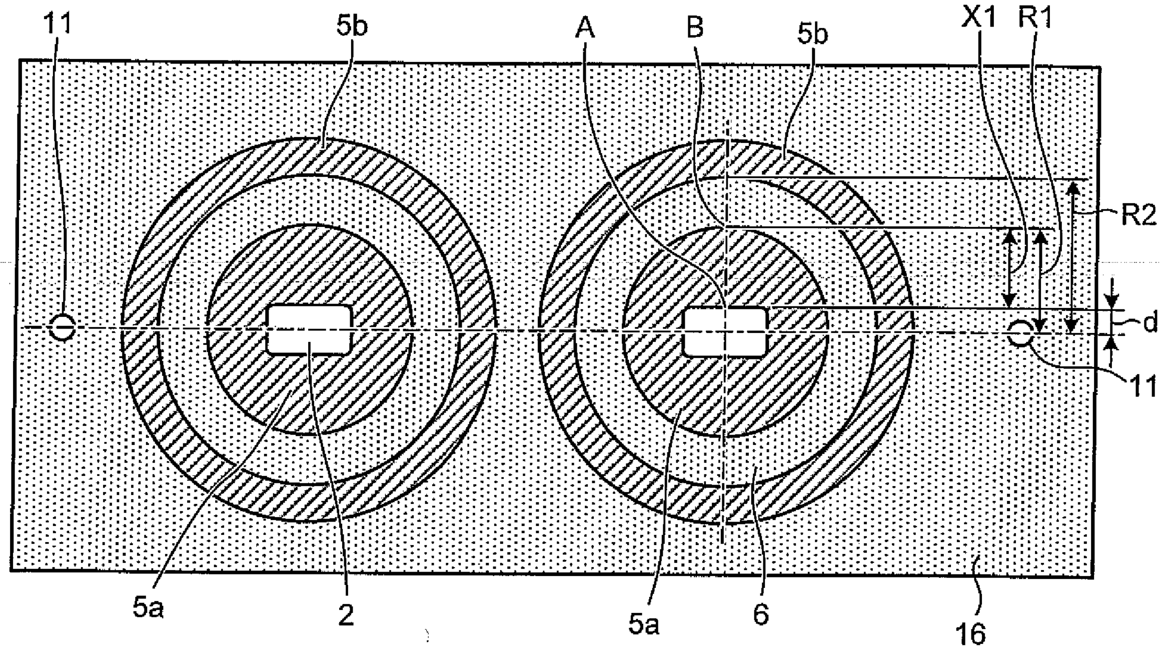
5b
9
9
13a
5a
12
15
16

FIG.9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R1
R2
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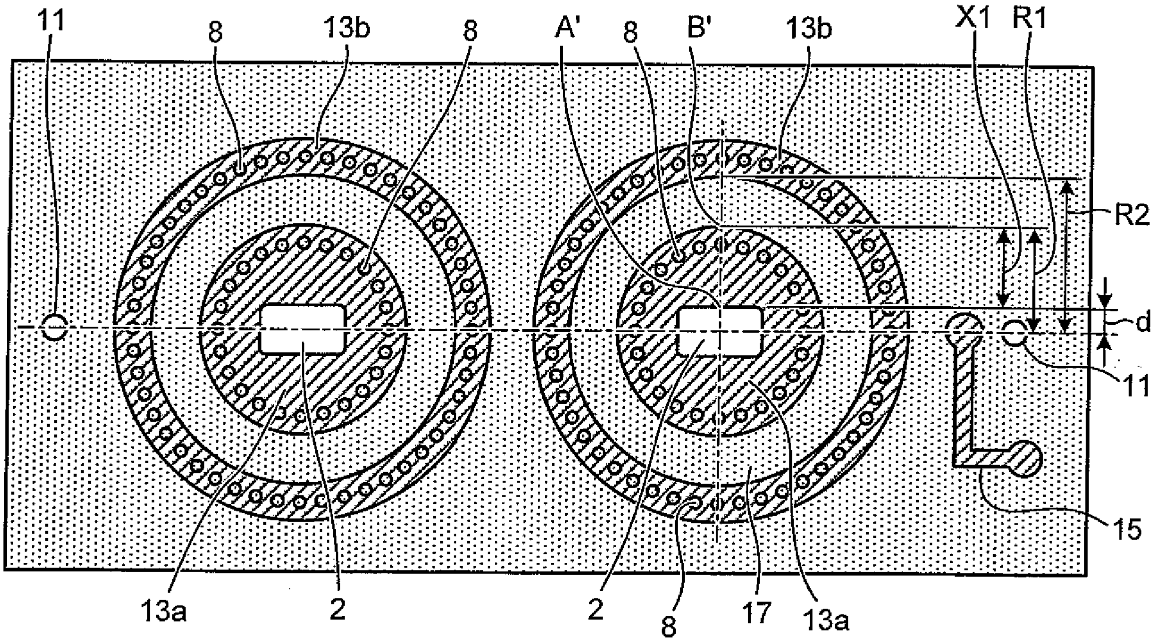
5a
6
16

FIG.10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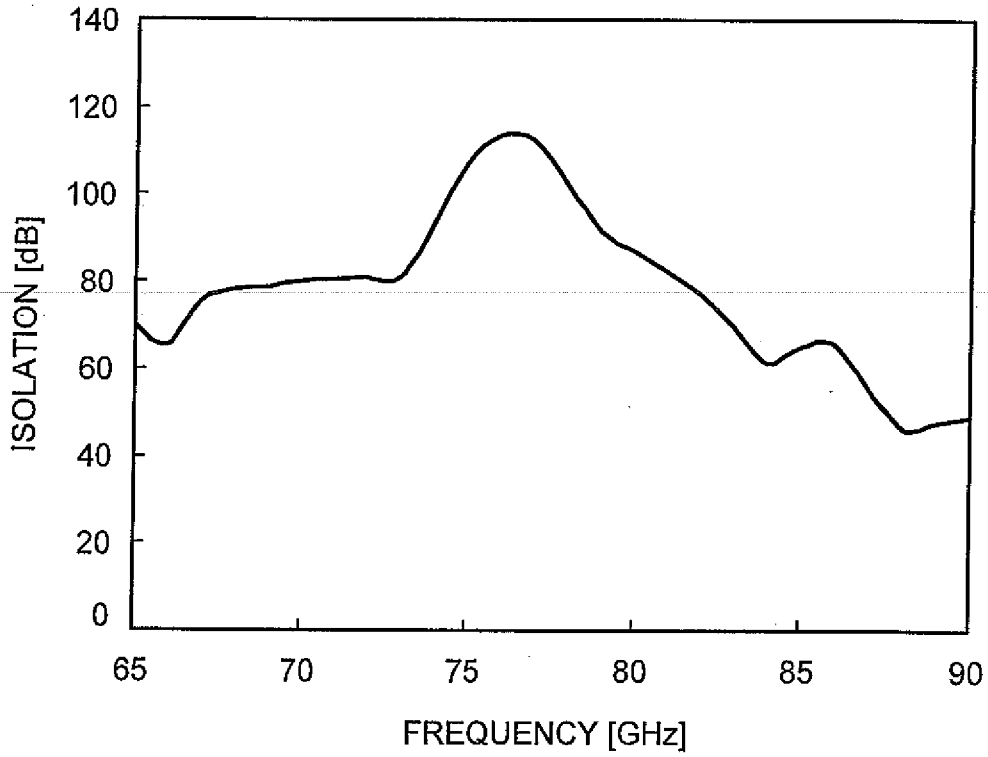
17
13a

FIG.11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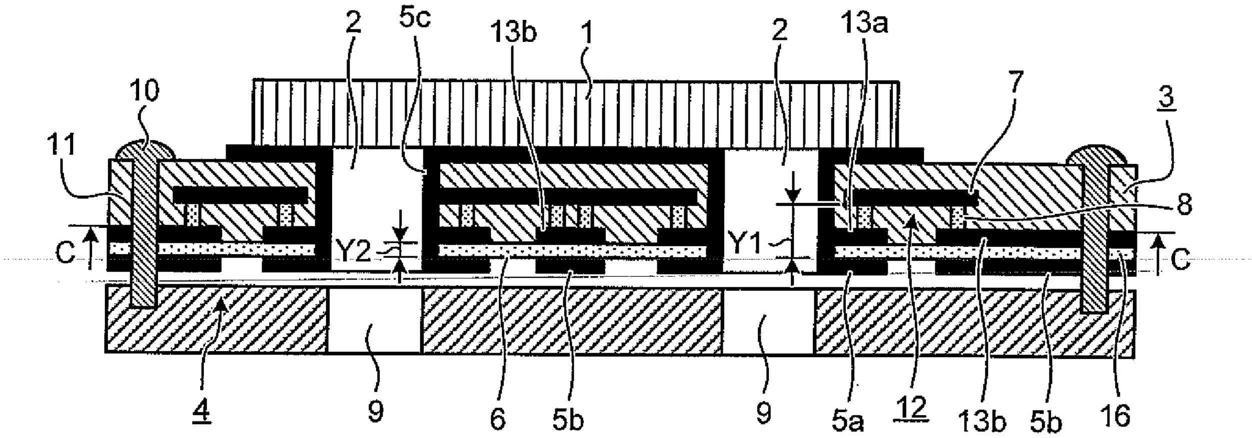
FREQUENCY [GHz]

FIG.12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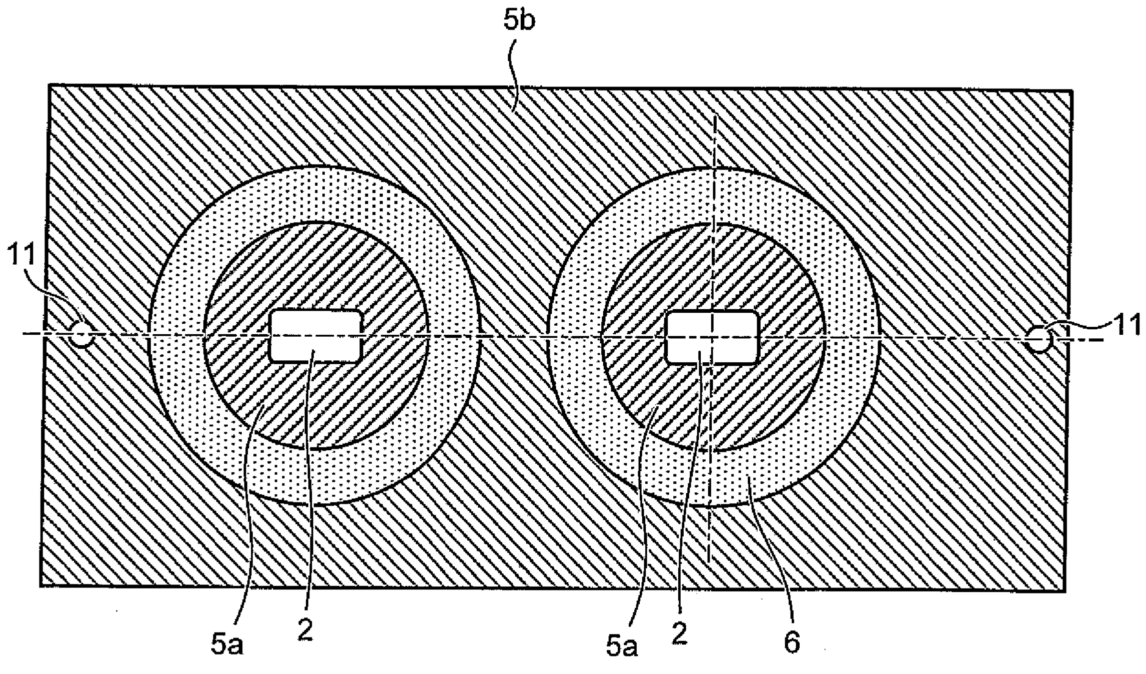
13b
5b
16

FIG.13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5a
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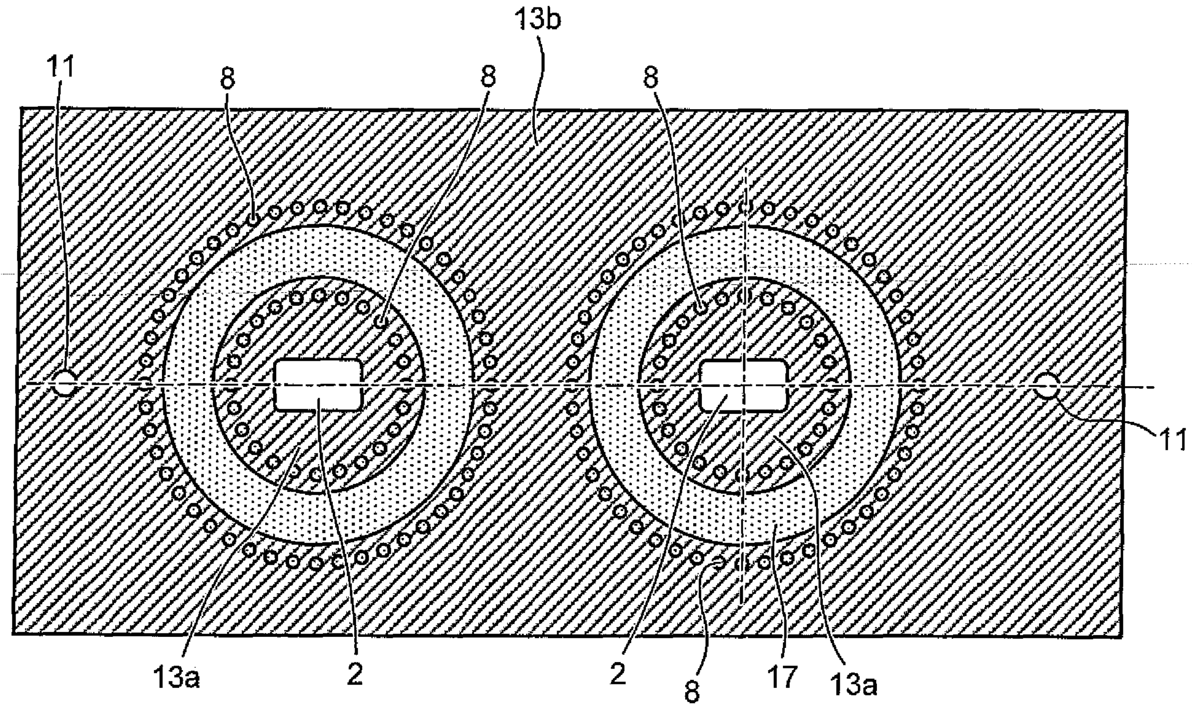
6

FIG.14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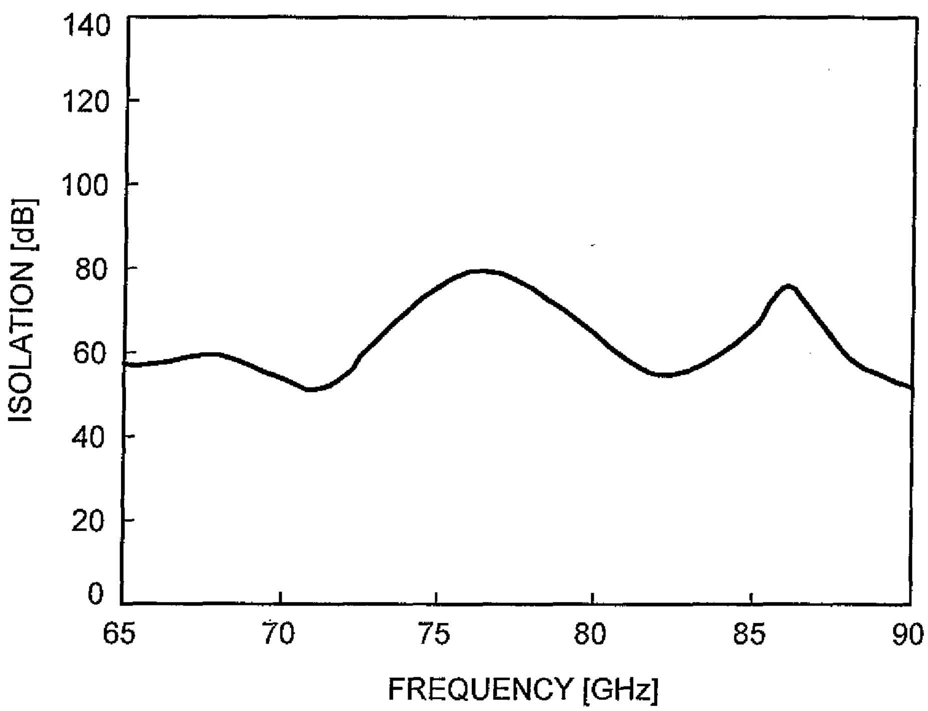
17
13a

FIG.15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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/063792

A. CLASSIFICATION OF SUBJECT MATTER
H01P1/04(2006.01)i, *H01P5/107*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01P1/04, H01P5/107

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E,A	JP 2008-113318 A (Mitsubishi Electric Corp.), 15 May, 2008 (15.05.08), Full text; all drawings (Family: none)	1-9
A	JP 2005-278016 A (Sumitomo Metal (SMI) Electronics Devices Inc.), 06 October, 2005 (06.10.05), Fig. 4; Par. No. [0022] (Family: none)	1-9
A	JP 2003-78310 A (Murata Mfg. Co., Ltd.), 14 March, 2003 (14.03.03), Full text; all drawings & US 2003/0042993 A1 & DE 10239796 A & CN 1404183 A	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 August, 2008 (21.08.08)	02 September, 2008 (02.09.08)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2001267814 A **[0003]**